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Soil Survey

of

The Roswell Area, New Mexico

By

W. G. HARPER

Bureau of Chemistry and Soils

In cooperation with the

New Mexico Agricultural Experiment Station

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SOIL SURVEY OF THE ROSWELL AREA, NEW MEXICO

By W. G. HARPER

AREA SURVEYED

The Roswell area, comprising 295 square miles, or 188,800 acres, in Chaves County, is situated in the Pecos Valley in the southeastern part of New Mexico (fig. 1). Roswell, the county seat of Chaves County, is in the northwestern part of the area. The area lies mainly on the west side of Pecos River and occupies a basinlike position as compared with the surrounding country. It averages about 10 miles in width and extends from about 5 miles north of Roswell to about 25 miles southeast of that city. It includes in part the area of a much earlier soil survey in this valley.[1]

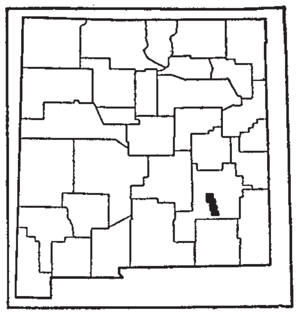

FIGURE 1.—Sketch map showing location of the Roswell area, New Mexico.

Plains ranging from level to rolling border the area on the east and north, and smooth gently rising plains extend westward a few miles where they merge with rolling hills and eroded upland plains. The uplands become steeper and rougher westward as they extend to outliers of the Sacramento Mountains. Summits in the Sacramento Mountains, which are about 50 miles west of the area, are about 5,000 feet above the valley or about 8,500 feet above sea level. Roswell is 3,566 feet above sea level.

The relief of this area is characterized by three distinct features—a smooth and broad gently sloping plain that occupies the larger part; comparatively level recent river flood plains or bottom lands, ranging from one-half mile to 3 miles in width, on both sides of Pecos River; and eroded escarpments which rise abruptly from 50 to as much as 250 feet above the river flood plain along much of the eastern margin of the area.

The broad plain slopes gently to the east and south and is dissected by a few streams that flow eastward to Pecos River. Besides these streams, which have cut from a few feet to 50 feet below the surface, a few depressions or flood watercourses extend eastward across, or part way across, the plain from the west. These depressions range from 100 to 300 feet in width and from 1 to 3 feet below the general level of the plain. In some places the plain merges almost imperceptibly with the former flood plain of Pecos River and

[1] MEANS, T. H., and GARDNER, F. D. A SOIL SURVEY IN THE PECOS VALLEY, NEW MEXICO. U. S. Dept. Agr., Div. Soils Field Oper. 1899, Rept. 64: 36–76, illus. 1900.

with the comparatively level former flood plains of the intermittent streams that dissect the upland plain. At other places the junction of the plains with the lower land is marked by a rather abrupt slope or break that ranges from a few feet to more than 30 feet in depth.

Pecos River, which flows through the area in a southeasterly direction, is the largest stream and serves as an outlet for the other streams. It meanders somewhat in places, and because the stream bottom consists of sands and clays and the depth of the flow ranges from a few inches at some seasons to 6 or more feet at other seasons, the situation of the main channel changes frequently. The former flood plain along the river is comparatively smooth and level. In places gently sloping alluvial fans have been built up by streams or flood waters originating in the higher adjoining land. These fans slope gently toward and merge with the more level land near the river.

The principal vegetation of the plains section consists of a sparse or moderately dense cover of grama, buffalo, and needle grasses, together with some sunflower, catclaw, and small mesquite on the well-drained uplands. A tall saltgrass, alkali sacaton (*Sporobolus airoides*), grows on gypsum soils and on the better drained salt-affected soils. On areas of bottom lands near stream channels, where the gypsum content is comparatively low but the salt content high, the short saltgrass (*Distichlis spicata*) is most common, and sedges and cattails occupy exceptionally wet or marshy areas. The tree growth consists of saltcedar and some willow in and bordering the bed of Pecos River and other streams.

Chaves County was organized from a part of Lincoln County in 1891; parts were taken from Chaves County to form part of Roosevelt County in 1903; and in 1917 parts were taken to form parts of De Baca and Lea Counties, and some land was annexed to Roosevelt County. Previous to the organization of the county this area was utilized principally for range purposes. The year 1889 marked the beginning of the expansion of irrigation from that afforded by a few short ditches on privately owned ranches to the present extensive system. Coincident with the development of irrigation, settlement of the valley increased. In 1900 the population of the county was 4,773, and in 1930 it was 19,549. Of this number 16,084 are native whites.

Roswell, with a population of 11,173, is the only city. Dexter and Hagerman are important towns. A branch of the Atchison, Topeka & Santa Fe Railway runs through the area, providing a transportation outlet which connects on the north with a main line of the Santa Fe at Clovis, N. Mex., and on the south with the main line of the Texas & Pacific Railway at Pecos, Tex. Oiled, paved, and macadam highways cross the valley from north to south and from east to west, providing outlets to the principal localities in other parts of New Mexico and neighboring States. The area is well supplied with telephones, schools, and churches.

CLIMATE

The climate is of the continental type typical of southwestern desert regions. It is characterized by low humidity, high evapora-

tion, moderately high summer temperatures, moderate winter temperatures, low rainfall, a high percentage of clear sunny days, a small amount of snow which usually melts a few days after it falls, and an absence of prolonged periods of extreme cold or oppressive heat. The prevailing winds are from the southwest, and the average wind movement is 7 miles an hour. High southwesterly winds, frequently carrying much dust, are common during the spring. The average length of the frost-free season is 206 days, from April 6, the average date of the last killing frost, to October 29, the average date of the first. Killing frost has been recorded as late as May 7 and as early as October 10. About three-fourths of the rainfall is well distributed throughout the growing season. The climate is invigorating and healthful. The drinking water is comparatively hard. Precipitation is not sufficient to produce profitable yields of crops, but with irrigation a large variety of early spring crops and crops that mature late in the fall may be produced. Alfalfa, grains, and some grasses provide some winter pasture for livestock.

Table 1, compiled from records of the United States Weather Bureau station at Roswell, gives the more important climatic data which are fairly representative of the entire area.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Roswell, Chaves County, N. Mex.*

[Elevation, 3,566 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1927)	Total amount for the wettest year (1919)	Snow, average depth
	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*	*Inches*
December	41.2	77	−10	0.66	0.35	0.24	3.2
January	39.2	83	−19	.53	.02	.02	2.5
February	42.5	83	−29	.57	.14	.15	2.1
Winter	41.0	83	−29	1.76	.51	.41	7.8
March	51.3	95	−2	.74	.10	5.19	1.2
April	60.6	96	17	.89	.01	3.70	.5
May	69.4	98	28	1.09	.04	1.00	0
Spring	60.4	98	−2	2.72	.15	9.89	1.7
June	76.3	106	43	1.67	2.00	4.02	0
July	78.9	105	53	2.26	1.13	.15	0
August	76.6	102	48	2.15	.54	.72	0
Summer	77.3	106	43	6.08	3.67	4.89	0
September	70.3	98	33	2.11	.17	6.33	0
October	59.5	92	19	1.42	.33	.62	0
November	48.1	87	−6	.85	.00	.55	2.7
Fall	59.3	98	−6	4.38	.50	7.50	2.7
Year	59.5	106	−29	14.94	4.83	22.69	12.2

AGRICULTURE

The early agriculture in the Pecos Valley consisted of livestock raising. In 1889 irrigation of farms in connection with livestock

ranches was practiced on only a few farms, but since then the acreage of land irrigated has increased and, following this increase, farming and the introduction of a variety of crops have been widely developed.

In 1899 alfalfa was the principal crop and was grown on 6,950 acres in Chaves County. In the same year the Federal census reports 774 acres devoted to corn, 466 acres to coarse forage, and 19 acres to sweetpotatoes. Livestock raising, dairying, and poultry raising were important. By 1909 the number of animals sold and slaughtered increased more than fourfold, and their value amounted to $2,435,267. Cereals, grains, hay and forage, vegetables, and all livestock products increased markedly in value. The 1920 census reported similar increases, both in volume and value of nearly all crops grown in the valley, but the 1930 census reported a decrease in the values and acreages of crops in 1929. Cotton was grown on 68 acres in 1919, and it proved so well adapted to the soils and climate of the valley that plantings were increased, and in 1929, 24,927 acres were devoted to this crop. With the exception of cotton, most of the crops grown in the area increased with the development of irrigation in the valley. After the slump in prices in 1920 the acreage of many crops decreased greatly.

The fertility of the soil is built up through the use of both barnyard manure and commercial fertilizers. Superphosphate has been used on alfalfa in this area since 1918, and about 10 carloads a year are used at present.

Much of the labor is done by the farmer and his family, but extra help is necessary during cotton-chopping and cotton-harvesting seasons. During the last few years 50 cents an acre has been paid for chopping cotton. Laborers kept through the year are paid about $1 a day and furnished with a house, milk, and a garden plot. Extra labor is employed during alfalfa-hay harvest, apple harvest, and the lambing season.

Most of the farms have good or fair houses and, in addition, barns, silos, and machine sheds; but some farms have only a house and a corral for the horses. Nearly all the farms are equipped with plows, harrows, and either tractors or horses. Where cotton is grown, two-row cultivators and stalk cutters are in common use, and three- and four-row cultivators are used with tractors. Spring-tooth harrows, disk harrows, clod-crushing rollers, planters, mowers, binders, and harvesting machines are among the equipment used. In 1931 about 60 percent of the farm work was done with teams, but at present about 90 percent of it is done with teams and 10 percent with tractors. Many of the farmers keep some chickens and pigs and one or two milk cows for home use.

In connection with cotton growing, ginning and the manufacture of cottonseed products are important industries in this area. Gins are located at Roswell, Dexter, Hagerman, and at other points, and a cottonseed-oil mill is at Roswell. Cotton is shipped to eastern and foreign markets, and the cottonseed cake is sold locally and in the livestock-raising areas of the Western and Midwestern States.

Dairying is important, and Jerseys are the principal dairy cattle. The cows are milked by hand, and most of the milk is marketed as butter or cream, although some whole milk is sold to supply the local demand. In April 1930, 2,155 cows were milked in Chaves

County, and the daily production of milk was 4,065 gallons. Most of the dairies are in the Roswell area.

Cattle raising is important in this part of New Mexico, and many of the farmers graze their cattle outside the irrigated area, but some cattle are brought into the area and pastured on grain or alfalfa fields or in the bottom lands near Pecos River. Hereford cattle are raised, and most of them are shipped east to feeding districts where they are fattened for market.

Sheep raising also is important. The 1930 Federal census reported 120,143 sheep in Chaves County, all of which are good-quality fine-wool sheep. Large numbers are kept in the area during the winter and spring until after the lambing season, and some lambs are kept until ready for market, when they are shipped east.

Poultry raising and hog raising are engaged in principally for home use and to supply the demands of local markets. The Federal census reports 8,988 turkeys raised in the county in 1929. The same census reports 2,605 hives of bees, most of which are in the Roswell area.

SOILS AND CROPS

The soils of the Roswell area have developed mainly from water-laid deposits. Waters responsible for the deposition have transported the material in stream channels and later deposited it on the broad gently sloping alluvial fans and on the rather level narrow flood plains that border the stream channels. The materials deposited by floods during the process of building up the alluvial fans or flood plains have differed in both texture and chemical character. Following deposition of this material, movements of moisture in the soil and the effects of climate and vegetation have influenced the further development and the characteristics of the soil materials. The depth of the soil material that is friable and easily penetrated by plant roots, the content of salts or carbonate of lime, and the drainage and aeration of the soil, together with climatic influences, are primary factors which have determined the possibility of producing the crops grown in this area.

The principal crops are cotton, alfalfa, grains, and hay (for forage), corn, grain sorghums, and vegetables.

Cotton was not extensively grown until after 1920, when it was learned that the soils and climate were well adapted to the production of this crop. Cotton is planted in April and May; chopped, irrigated, and cultivated during the growing season; and picked in October, November, and December. The area is free from harmful diseases and pests, although some angular leaf spot affects cotton, and the leaf worm sometimes damages the crop by eating the leaves. The leaf worm may be controlled by sprays.

Alfalfa occupies the second largest acreage. It is grown principally for hay, and some is harvested for seed. Some fields of alfalfa are pastured in the spring and fall, and, generally, four or five cuttings a season are made. The hay is baled, and most of it is shipped to Texas and other places where it is used for feeding cattle and sheep. Alfalfa is left on the land from 4 to 8 or more years, or until the field becomes very weedy or pests are prevalent, when it is plowed under, and cotton is grown until the land is free from

weeds and pests. Wheat, barley, and oats or wheat with alfalfa are grown and used for fall and spring pasture, and later in the spring they are cut for hay.

Corn occupies a rather large acreage, and grain sorghums also are important. The grain is harvested, and most of it is used locally. Corn and sorghums cut for silage are important crops. Vegetables are grown near Roswell and are marketed locally. Apples are marketed locally or shipped to points in other parts of New Mexico and to Texas.

The distribution of crops in the area and the growing of specific crops on certain soils has been partly due to selection and to individual suitability of crops to soils. Fruits are grown on the deep well-drained upland soils, and truck crops are extensively grown on the darker soils in the bottom lands bordering Hondo River. Accumulations of "alkali" salts and the presence of gypsum have, in part, determined the kind of crop grown on certain soils. The availability of water for irrigation and the height to which water must be pumped are other determining factors in the distribution of crops and, to some extent, the kind of crops grown. A rather large area of land near Orchard Park is not cultivated because the water-yielding strata in this locality are of finer texture than elsewhere in the area and the flow of wells is too small to supply irrigation demands. A high water table, salt accumulations, excessive quantity of gypsum, and poor-quality soils are other factors that limit the use of the land for cultivated crops. The potential fertility of a soil does not always give a clear idea of its possible profitable productivity, but such a determination, together with the inclusion of other influencing factors, is essential to profitable crop production.

The classification of the soils of this area is based on the field characteristics of the different soils, and they are divided into soil series which include closely related and similar soil types. The soil types differ one from another mainly in texture which is determined by the relative quantities of the various-sized particles of sand, silt, and clay in their composition.

The earlier survey (in 1899) in this valley,[2] one of the first to be undertaken in the United States, represents pioneer work in soil surveying and classification. In the field mapping and classification only a few soil types were recognized, and these were designated by local names. Since the time of the earlier survey, the system of soil classification with regard to soil series relationships has been developed. The present survey is undertaken with the benefit of past experience, development of field methods and technique, and improved equipment. These soils have been differentiated and delineated on the map in much greater detail, and soil type names are expressive of soil relationships which were not expressed in the earlier report. The soil names used in the early report, therefore, have no significance in the classification and nomenclature of this report.

In the following pages, the soils of the Roswell area are described in detail, and their agricultural relationships are discussed; their location and distribution are shown on the accompanying soil map; and their acreage and proportionate extent are given in table 2.

[2] By T. H. Means and F. D. Gardner.

TABLE 2.—*Acreage and proportionate extent of the soils mapped in the Roswell area, New Mexico*

Type of soil	Acres	Per-cent	Type of soil	Acres	Per-cent
Reeves loam	37,056	19.6	Arno clay loam	4,864	2.6
Reeves fine sandy loam	6,080	3.2	Arno clay loam, better drained phase	3,136	1.7
Reeves clay loam	30,656	16.2	Arno clay	3,008	1.6
Reagan clay loam	20,096	10.6	Arno very fine sandy loam	2,496	1.3
Reagan clay	1,664	.9	Arno loamy fine sand	1,088	.6
Reeves loam, gypsum-substratum phase	8,512	4.5	Pecos clay	2,112	1.1
Reeves clay loam, gypsum-substratum phase	3,776	2.0	Pecos loam	768	.4
Reeves chalk	22,144	11.7	Navajo loam	448	.2
Reeves loam, gravelly subsoil phase	128	.1	Navajo fine sandy loam	1,536	.8
Pinal gravelly loam	5,888	3.1	Navajo clay loam	832	.4
Pinal loam	8,960	4.7	Pecos loam, gray-subsoil phase	1,344	.7
Pinal clay loam	640	.3	Peat	1,152	.6
Arno loam	4,480	2.4	Dune sand	1,984	1.1
Arno loam, better drained phase	2,048	1.1	Rough broken land	3,328	1.8
Arno fine sandy loam	3,328	1.8	River wash	2,944	1.6
Arno fine sandy loam, better drained phase	2,240	1.2	Quarries	64	.1
			Total	188,800	------

UPLAND SOILS WITH WEAKLY CEMENTED LIME AND GYPSUM SUBSTRATA

The soils of this group include the light-brown soils of the Reeves series, together with associated bodies of darker-colored Reagan soils which have been modified by overwash of dark-colored alluvial sediments or by the incorporation of organic matter.

LIGHT-COLORED SOILS

The typical Reeves soils have light-brown or pale reddish-brown surface soils containing a large quantity of lime, underlain by feebly cemented subsurface layers and subsoils containing small flecks of accumulated lime. The lower part of the subsoil and the substrata are of somewhat heavier texture, are of pale pinkish-brown or pale olive-brown color, are cemented by and much mottled with lime and gypsum, and contain a few lime and gypsum nodules and rust-brown iron stains. Under moist field conditions the surface soils are pale reddish brown, and the lower lying materials of higher lime content become lighter gray when dry. Although the subsurface soils and subsoils are compacted and feebly cemented, the surface soils are granular and friable under irrigation and cultivation, breaking down into soft clods and fragments. Some of the deeper materials are plastic when wet and become hard when dry, but they soften again when moistened.

The light-colored soils of this group include Reeves loam, Reeves fine sandy loam, and Reeves clay loam. With the exception of a few small sags and local depressions, these soils are well drained and free from "alkali" accumulations, and they are among the most extensive and productive soils in the area. They are used principally in the production of cotton, alfalfa, corn, grain sorghums, grains cut for hay, and tree fruits. Apples are the principal tree fruit, and small acreages are devoted to peaches, pears, plums, prunes, cherries, and grapes. Cotton yields average about a bale an acre, alfalfa about 3 tons, corn for silage about 8 tons, grains cut for hay about

3 tons, apples about 4 boxes a tree, peaches about 3 boxes, and pears about 2 boxes.

Reeves loam.—The topsoil of Reeves loam is light-brown or pale reddish-brown highly calcareous friable loam of small-crumb or single-grain structure. In most places it contains many plant roots but not much other organic matter. Below a depth of about 8 inches, the material is very much like the topsoil but does not contain so many plant roots, and the soil is firmed or slightly cemented, presumably by carbonate of lime. This horizon extends to a depth of about 20 inches below the surface where the material becomes slightly more gray, owing to the accumulation of some carbonate of lime. The carbonate layer is similar to the upper soil layers in texture, structure, and friability. At an average depth of about 30 inches, the material grades downward into heavier textured material, in most places heavy loam or light clay loam. The basic color of the soil remains olive brown or pale reddish brown, but the increased number of carbonate of lime flecks gives it a slightly more gray cast. A few rust-brown iron mottlings occur in this horizon. At a depth of 72 inches below the surface and extending to a depth of 96 inches is slightly compact weakly cemented olive-brown clay which becomes light grayish brown when dry. It contains many gray mottlings, where flecks and nodules of carbonate of lime have accumulated, and a few rust-brown iron stains are present. Below this layer is highly calcareous weakly cemented slightly compact clay that contains a few gypsum crystals but not many carbonate of lime nodules. This material extends to a depth of 10 feet or deeper.

The area of Reeves loam in sec. 31, T. 10 S., R. 25 E., has a higher accumulation of carbonate of lime than is typical of this soil. The carbonate is closer to the surface and consists of many nodules.

Reeves loam, being rather friable to a depth of 10 feet or more, is easily penetrated by deep-rooted crops. The high content of carbonate of lime, with which are associated small quantities of gypsum and other salts, may have some detrimental effect on fruit trees but may be of value to cotton and related crops. This soil occurs on smooth gently sloping upland plains and is generally well drained. The slope of the land and the amount of rainfall are such that erosion is not serious, and the cost of cultivation, irrigation, and handling of crops is comparatively low.

This is locally rated a very good cotton, corn, and alfalfa soil. Fruits, principally apples, are produced, and the trees are reported to thrive very well in some orchards until from 18 to 24 years of age, when they seem to weaken or die. Many farmers attribute this result to the high content of carbonate of lime, associated gypsum, and other salts in the subsoil. Alfalfa yields from 2 to 4 tons an acre, corn about 35 bushels, and cotton about 1 bale. Apples average about 4 boxes a tree. Many crops adapted to this section are produced on this soil, and good yields are reported. Dairying and poultry raising are important types of farming.

Reeves fine sandy loam.—Reeves fine sandy loam differs from Reeves loam mainly in the lighter texture of the topsoil and in the lighter gray color of the underlying soil material. Much of this soil occurs north of Roswell, where it is used for the production of apples. The land is easily cultivated and irrigated and is rather desirable for

orcharding, but the selection of this soil for orchards was not entirely due to soil characteristics, as the area north of Roswell was selected because it has slightly better water and air drainage than areas at lower elevations. Here, also, the height to which water must be lifted for irrigation is greater than at the lower elevations, and this feature, to some extent, precludes the production of low-priced crops. Where this soil is used for general crops, it is very easily cultivated and handled, but the yields obtained in general are not so high as those on Reeves loam. This soil, like Reeves loam, is well drained and is free from harmful accumulations of "alkali."

An included body of soil that is not typical of Reeves fine sandy loam occurs at the margin of the area about 2½ miles southwest of Roswell. Here the topsoil, extending to a depth of 3 feet, consists of wind-laid loamy fine sand, and below this is dark-brown or black clay loam that contains a few gravel. In other characteristics this soil is similar to the typical soil. It is not cultivated but is covered by some grasses, weeds, and a few shrubs.

Reeves clay loam.—Reeves clay loam is very similar to Reeves loam and Reeves fine sandy loam, but the topsoil is heavier. This soil is extensive and occurs principally in the southwestern part of the area.

Much of the land is used only for pasture, but where cultivated it is used principally for the production of alfalfa and cotton, although corn, grains, and some fruits and vegetables are produced, and good yields are reported.

This soil is handled very much like Reeves loam, but, because of the heavier texture, it usually requires more power to plow and pulverize it. This is a well-drained upland soil free from harmful accumulations of salts, and it is well adapted for the production of most of the crops grown in the area.

DARK-COLORED SOILS

The dark-colored soils of this group include Reagan clay loam and Reagan clay. These soils occupy lower positions than the Reeves soils, are not so well drained, and originally were subject to a high water table and an accumulation of "alkali" salts.[3] Much of the land has been reclaimed by drainage, but local areas of poor drainage "alkali" accumulation are still included.

These soils are of higher organic-matter content than the Reeves soils, and the reclaimed or better drained areas, which are somewhat more productive, are utilized for cotton, corn, alfalfa, and vegetables. The poorly drained and salt-affected areas are much lower in quality and in crop-producing value. Such land must be drained and leached of salts and in some places fertilized before it will produce crops equal to those grown on the salt-free areas.

Reagan clay loam.—Reagan clay loam is very much like Reeves clay loam, but the topsoil is darker. This soil occupies a position where flood waters have spread out over the surface and deposited fine-textured dark-brown material or where moisture conditions have

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[3] As used in this report, the term "alkali" refers to an excessive accumulation of mineral salts not necessarily alkaline in reaction, unless specifically stated. It is thus used in the local agricultural, rather than in the correct chemical, sense.

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favored the accumulation of vegetable matter that has imparted a dark color to the topsoil. The small area in sec. 31, T. 10 S., R. 25 E., has more carbonate of lime nodules in the subsoil than other bodies of this soil, and it approaches conditions that occur in the subsoils of the Pinal soils.

Reagan clay loam produces slightly higher yields of cotton, corn, alfalfa, grain, and vegetables than are obtained on Reeves clay loam or Reeves loam. This soil occurs in large areas east and south of Roswell and near Dexter and Hagerman.

The soil in the areas near Dexter and in those from 3 to 5 miles west and southwest of that place have a greater average depth to the horizon of carbonate of lime accumulation, which is more weakly developed than typical, and produces slightly higher yields than the soil in other areas. The area along the intermittent drainageway about 3 miles southeast of East Grand Plains School and the areas 3½ and 5½ miles southwest of Hagerman occur on slopes to depressions, are of heavier texture, are grayish brown or brownish gray, are much higher in carbonate of lime and gypsum than typical, and are of comparatively low productivity.

Much of the soil at one time contained harmful quantities of salts. A few areas still contain sufficient salts to be harmful to crops, and in some places where the surface soil is free from salts the subsoil contains rather excessive accumulations. The installation of drainage systems and the practice of flooding to dissolve the salts and wash them down through and out of the soil with the underdrainage waters have reclaimed large areas of this soil, and the land is now producing very good yields of crops of many kinds. For reclamation, effective drainage is necessary previous to flooding. In most places underdrainage is obtained readily by a system of underground drains, but in some localities east of Roswell, layers of clay impede the movement of water through the subsoil or substrata.

Reagan clay.—Reagan clay is similar to Reagan clay loam in mode of formation, adaptability to crops, and occurrence, and it also is somewhat modified through the incorporation of organic matter. The topsoil is heavier than that of the clay loam, and therefore more power for plowing and pulverizing the soil and for preparing the seedbed are required. Alfalfa, cotton, corn, and grain are the principal crops grown, and good yields are obtained.

The three areas lying from 3 to 5 miles west and southwest of Dexter have thicker layers above the zone of carbonate of lime accumulation and contain less carbonates than other bodies of this soil. Two areas—one about 3½ miles southwest and one about 5½ miles southwest of Hagerman—differ from the typical soil in that they occupy slight depressions, are grayish brown, of adobe structure, and of heavy clay texture. These two areas and a part of the area southwest of the L. F. D. School contain sufficient salts to affect crops slightly. Probably the effects of salts in the body near the L. F. D. School will disappear following a few years' irrigation, but utilization of the two areas in the depressions for cultivated crops is unlikely, owing to the cost of pumping water and to the extreme difficulty in providing drainage for their reclamation.

UPLAND SOILS WITH EXCESSIVELY DEVELOPED LIME AND GYPSUM SUBSTRATA

In the soils of this group an excessive development or accumulation of lime and gypsum in the subsoil and underlying material has taken place. The subsoil is of rather soft and mealy or granular to massive structure, is readily permeated by water, and does not have the firmly cemented development of the soils having firmly cemented hardpan substrata. The surface soil materials are light brown in color and are representative of the typical Reeves soils, from which these soils differ in the more pronounced character of the underlying materials. The surface soils are productive, but agricultural utilization is greatly limited by the slight depth to the gypsum or hardpanlike substratum, which is an unfavorable feature. The soils are of decidedly lower quality than those of the preceding group. In areas of these soils where the depth to the gypsum beds or hardpanlike material is 3½ feet or more, yields of corn and grain compare well with the yields obtained on the better soils, but the deeper rooted crops, such as alfalfa, cotton, and tree fruits, return smaller yields. The bodies having the more shallow surface soils are unproductive, and in local areas of poor drainage and salt accumulation, yields are low or negligible.

Reeves loam, gypsum-substratum phase.—Reeves loam, gypsum-substratum phase, differs from typical Reeves loam in that it is underlain, at a depth ranging from 14 inches to 6 feet, by a substratum of gray or white gypsum. The gypsum, which has associated with it different quantities of carbonate of lime, is massive, but after being broken up is very mealy; it is in general weakly cemented but can be drilled into with the soil auger; and water passes through it readily though not excessively fast. It seems to be almost without plant nutrients, and wherever it occurs it usually limits the growth of most plant roots, but other than limiting the depth of the rooting zone the gypsum layer does not seem very harmful to crops. In most places it contains rather large quantities of soluble salts, and in places where water moves through this material into the upper soil layers some harm results from the salts moved in solution and deposited in the upper soil layers.

The principal areas having the more favorable thickness of soil material occur east and south of East Grand Plains School, north of Dexter, and south of Hagerman between the Santa Fe Railway and Pecos River. That part of the area lying about 2 miles south of East Grand Plains School, near the body of Reeves fine sandy loam, has a topsoil of fine sandy loam texture. The surface relief of this area is in general smooth, and the soil occupies gently sloping alluvial fans.

The more shallow bodies, in which the gypsum substratum occurs within a depth of 2½ feet, are scattered rather widely throughout the area, mainly east of the Santa Fe Railway and near areas of Reeves chalk. The body about 1 mile northeast of Berrendo School has a fine sandy loam topsoil. The two areas east of Pecos River and north of United States Highway No. 380 have been developed from materials that had their origin in the eroded Permian "Red Beds" formations that occur at the eastern margin of the area

surveyed. The topsoil of these bodies is redder and consists of finer grained sediments than is typical of most of this soil.

Natural drainage is good in some places but very poor in others, and in the latter places artificial drainage has resulted in improving the productivity of the soil. Some areas are free from harmful quantities of salts, but others are slightly, moderately, or strongly impregnated with salts. Most of the salt-affected areas are covered by a stand of tall saltgrass, or alkali sacaton. Reclamation of the deeper of these salt-affected areas may be accomplished by a system of underdrainage that will keep the water table at a depth of 6 feet or more below the surface of the ground. Following installation of such a drainage system, flooding the land to dissolve and wash the salts down and out of the soil is necessary. Reclamation of some of the more shallow areas by drainage and flooding may be feasible, but many of the bodies occur in places where construction of an adequate drainage system would be expensive. Some bodies, including the one on the east side of Pecos River in the northern part of the area, not only have a high content of salts but areas of adjoining soils are also high in salt content, and in such places intercepting drains to catch the waters seeped from the adjacent areas are necessary before reclamation is completed.

On the areas of deeper soil free from harmful accumulations of salts, cotton, alfalfa, corn, and grains are grown, but yields are somewhat variable and in part depend on the depth of soil over the gypsum bed. Where the gypsum bed is about 6 feet below the surface the value of this soil compares favorably with that of typical Reeves loam.

Much of the shallower soil is not cultivated but supports a growth of grama or saltgrasses, but where the land is cultivated, alfalfa, cotton, and corn are the principal crops, fair yields of which are reported. Much of the land is affected to some degree by salt accumulations.

Reeves clay loam, gypsum-substratum phase.—The gypsum-substratum phase of Reeves clay loam is comparable to the gypsum-substratum phase of Reeves loam, and its mode of formation, crop adaptations, and general characteristics are very similar, but it differs from the loam in texture. Its topsoil characteristics are similar to those of typical Reeves clay loam.

Like the gypsum-substratum phase of Reeves loam, the thickness of the soil material overlying the gypsum beds differs considerably in different places. Most of the shallower bodies of this soil are in the northern part of the area, but one small area is south of Hagerman. Most of these bodies are moderately or highly affected by accumulated salts and are producing principally saltgrass which is utilized to some extent for pasture. Most of them are adjacent to areas of Reeves chalk, and drainage and reclamation, because of the expense involved and the poor quality of the soil following reclamation, are not recommended.

The small area east of Pecos River 4 miles northwest of Spring Mountain Valley School has a thicker surface soil, is redder, and contains more gypsum than is typical of this soil. That part of the area 3 miles southeast of East Grand Plains School and east of Northern Canal has a surface soil that is more red than typical.

Although small areas of the deeper soil have good drainage and are free from harmful quantities of salts, most of the land is affected to some degree by salt accumulation, and crops are slightly or moderately damaged. Possibly drainage and reclamation could be provided in some places but would be very expensive. Alkali sacaton, a saltgrass, grows on most of this soil.

Reeves chalk.—Reeves chalk consists of a gray or white ashy material throughout the entire soil which, in most places, is slightly firm but is only feebly cemented and may be cut easily with a soil hammer or shovel. The material seems to have a much higher content of gypsum than of any other salts, although it is highly calcareous and contains much carbonate of lime. It is rather pervious to water but is high in water-soluble salts. In a number of places soft layers in the soil or in the substratum have been washed away through underground watercourses, and the surface has sunk, leaving steep-sided holes or basins ranging from 1 foot to several feet in depth.

In some places this soil represents a stratum of material that was a part of the Permian deposition. In other places it represents a more recent accumulation of gypsum, carbonate of lime, and other minerals that have probably formed in poorly drained areas where seepage water accumulated large quantities of minerals, or where highly impregnated seepage waters evaporated, leaving large deposits of gypsum and other materials.

The surface relief is smooth or slightly hummocky, and the land slopes gently or is slightly rolling, depending on the extent of erosion. The large area northeast of Roswell is much more rolling than other areas of this material.

A sparse stand of a tall saltgrass, alkali sacaton, is the principal vegetal growth on this soil. The land is practically worthless for farming and has a very low pasture value.

UPLAND SOILS WITH LOOSE GRAVELLY SUBSTRATA

The upland soils with loose gravelly substrata are represented by Reeves loam, gravelly subsoil phase. This soil is inextensive, of low water-holding capacity, and subject to drought. It is uncultivated and is utilized only for the scant pasture it affords.

Reeves loam, gravelly subsoil phase.—The gravelly subsoil phase of Reeves loam is related to typical Reeves loam only in the characteristics of the upper soil horizons which are very similar. At a depth ranging from 8 inches to as much as 3 feet below the surface the material grades into rather loose gravelly loam or gravelly sand, which extends to a depth of 6 feet or deeper. The gravelly materials have been transported from the mountainous sections west of the area and have been deposited along former stream channels, whereas the surface materials have been deposited subsequently on the gravelly layer. The gravel, which are mainly of sedimentary origin, are rounded and well water-worn, and, because of these features and the lack of soil material in the gravelly layer, the subsoil is exceptionally leachy.

This soil is not cultivated and supports only a scant stand of grasses. If water were available for irrigation, a few shallow-rooted crops could be produced, but, because of the leachy subsoil, it

is probable that this soil will never be of much value for crop production.

A small area is 2 miles west of Dexter, three areas lie about 5½ miles northwest of Dexter, and two areas are 2 miles southwest of Roswell.

UPLAND SOILS WITH FIRMLY CEMENTED LIME CARBONATE HARDPAN SUBSTRATA

LIGHT-COLORED SOILS

The light-colored soils of this group are represented by the gravelly loam and loam members of the Pinal series. The surface soils are light grayish brown or pale reddish brown, are highly calcareous, and contain hard lime carbonate nodules or fragments of light-gray or white firmly cemented massive and rocklike lime hardpan which underlies the surface soils at a slight depth. The Pinal soils are somewhat similar to the Reeves soils, but they have characteristics of a soil that is overmature or abnormally developed. Cotton and some other crops are grown on a few areas of the deeper soils, but yields are low. These soils comprise good grassland and are utilized mainly for pasture.

Pinal gravelly loam.—Pinal gravelly loam is the most extensive soil in this group. It has a light grayish-brown friable gravelly loam topsoil. Many hard angular carbonate of lime fragments occur on the surface and in the soil material. The gravel consist mainly of both rounded and subangular water-worn sandstone and quartz and include some gravel which are probably of igneous material. The topsoil extends to an average depth of about 10 inches where it is underlain by a gray or white firm lime-cemented gravelly layer which ranges in thickness from about 10 inches to 2 feet. This material is somewhat porous but is very hard and does not contain many plant roots. At a depth ranging from 20 to 30 inches below the surface this cemented layer grades rapidly downward into material that is not cemented but consists of loose friable light-gray or white gravelly loam material with a high content of lime.

This soil has been developed from materials that have been transported from the higher mountainous sections west of the area and deposited on the alluvial-fan slopes or upland plains of the Pecos Valley. Following deposition, carbonate of lime accumulated in large quantities and cemented a definite layer in the soil, determined by depth to which rainfall penetrated, or by the height of the water table. This soil occurs most extensively in the northwestern and southwestern parts of the area, where it occupies smooth-surfaced slightly rolling land. Many bodies occur as low ridges or knolls, that stand from 1 to 4 feet above the surface of the surrounding plain. The rainfall of this section is low. Internal drainage is not well developed, but surface run-off in most places is rapid. This soil is free from harmful accumulations of alkali salts, and it supports a sparse or moderate stand of *Gutierrezia* and some grasses.

Pinal loam.—Pinal loam, in mode of formation, occurrence, and surface relief, is essentially the same as Pinal gravelly loam, but it lacks the gravel. A few areas of this soil occur where the upland slopes break and merge with lower lying lands. In such locations, the high accumulation of carbonate of lime probably has been de-

posited where seepage waters have approached the surface, evaporated, and deposited their load of soluble material.

Most of the high-lying areas of this soil are free from excessive accumulation of salts, but some bodies that occur near the lower fan slopes have moderate or high accumulations of "alkali". Most of the land is not cultivated but is used for pasture. Cotton is grown on a few areas, and from poor to fair yields are reported.

DARK-COLORED SOILS

The dark-colored soils of this group are represented by Pinal clay loam. This soil has a surface soil which is somewhat heavier in texture and darker in color than the typical Pinal soils. The hardpan layer occurs at greater depth, and the soil is much superior to the typical lighter colored Pinal soils, in which the hardpan lies at a slight depth. The deeper, well-drained areas are utilized for alfalfa, cotton, and corn.

Pinal clay loam.—Pinal clay loam has a clay loam topsoil that is very similar to the topsoil of Reagan clay loam. At a depth ranging from 15 inches to 4 feet the topsoil lies on an indurated carbonate of lime layer which is very similar to the cemented layer in Pinal gravelly loam but generally contains few or no gravel. The material is slowly pervious to water, but it is too hard for root penetration.

This soil occurs on the smooth slopes of the upland valley plain in association with the Reeves soils and in a few places on the steeper slopes where the upland plain breaks away to merge with lower lying soil areas. Most of this soil is free from salt accumulations, but there are large quantities in one body about 2½ miles east of Roswell. In this body, although some artificial drainage has been installed, adequate drainage is lacking and a high water table occurs during part of the year, therefore salts continue to accumulate.

Most of this soil is cultivated. Alfalfa, cotton, and corn are the principal crops grown. Where the soil material is 3½ feet or more thick over the hardpan layer, good yields are obtained, but where the lime layer is close to the surface, yields are comparatively poor.

STREAM-VALLEY SOILS WITH NO HORIZON OF LIME AND GYPSUM ACCUMULATION

The soils of this group consist of recently accumulated alluvial deposits representing parent geological materials which have not as yet been noticeably acted on by soil-building processes or which at best represent only an incipient stage in soil-profile development. These soils are of high lime content and effervesce vigorously with dilute hydrochloric acid. Various quantities of gypsum are associated with the lime. The lime and gypsum, however, are much more uniformly disseminated than in the older soils of the uplands, in which the soil-building processes have had time to express themselves, and as yet no definite subsurface or subsoil horizon of accumulation of the soluble minerals has developed. Conspicuous mottling by lime segregations or layers of cementation are generally absent.

Some of the lower lying areas are subject to overflow during wet periods or stream flood stages, and the soils include areas having a high water table and an "alkali" accumulation. Where well drained

and free from salts, the land is highly productive. These soils include the reddish-brown or dull-red soils of the Arno series and the dark-colored soils of the Pecos series.

REDDISH-BROWN OR DULL-RED SOILS

The Arno soils are typically light reddish brown, pronounced reddish brown, dull red, or chocolate brown. The subsoils consist of parent stream-laid materials of various textures and stratified character. These soils have been derived from geological materials of a wide range, but mainly from calcareous shales and sandstones. They have undergone but little leaching since deposition and are of somewhat higher organic-matter content than the soils of the upland plains. They include some of the most productive soils of the area, but the low-lying areas are subject to deficient drainage, overflow, and accumulations of seepage waters and alkali salts. Some included areas represent somewhat older weathered material which is discussed under a separate group of soils.

The better drained and salt-free areas of the Arno soils are deep, friable, and, with the exception of the wind-blown loamy fine sand type, are highly productive. They are less extensive than the soils of the Reeves series, but, owing to their greater depth, are better adapted to tree fruits and other deep-rooted crops. The coarser textured soils are warmer and better adapted to the growing of early truck crops, sweetpotatoes, and early corn, whereas the clay loam and clay types produce higher yields of alfalfa, cotton, and grains. Most of these soils occupy comparatively low lying areas where air drainage is not so good and frosts are more frequent than in the apple-growing sections. Disregarding air drainage and frost, the coarser textured soils of this group are better for tree fruits than the soils at present most widely used for apple production.

Arno loam.—Arno loam is characteristic of the soils of this group. The 10-inch topsoil is rich reddish-brown or dull-red friable calcareous loam. Below this and extending to a depth of more than 6 feet the material is similar to the surface soil, except in color which is chocolate brown when dry and becomes of more pronounced red color when wet.

This soil consists of material that has been eroded principally from the areas through which the upper tributaries of Pecos River pass and in which red sandstones and shales predominate. This is probably the cause of the somewhat red color. The soil materials are high in content of gypsum and carbonate of lime, and they are composed of well-weathered minerals in which only rounded quartz fragments the size of fine sand are distinguishable.

Several areas of this soil occur on both sides of Pecos River. The surface relief is smooth, with in most places a slight slope paralleling the river. Drainage waters pass through the soil freely, but, because many of the areas are situated where the water table is high, they are moderately or highly affected by accumulations of salts. Areas of this soil free from harmful accumulations of salts are used for growing cotton, corn, alfalfa, and truck crops. The land is very easy to cultivate, lends itself well to irrigation, and very good yields of all the crops are obtained.

Arno loam, better drained phase.—The better drained phase of Arno loam is very similar to typical Arno loam. The only apparent differences are the color, typical Arno loam being slightly more red than soil of the phase, and its occurrence along small tributary streams resulting in somewhat better drainage. Some of the areas about 3½ miles west of Hagerman, adjacent to areas of river wash along Felix River, have gravel in the subsoil.

Areas of this soil, nearly all of which are well drained and free from salt accumulations, lie adjacent to Berrendo, Hondo, and Felix Rivers. The land is used for growing cotton, alfalfa, corn, grains, and truck crops, and very good yields are reported.

Arno fine sandy loam.—Arno fine sandy loam differs from Arno loam only in the texture of the surface soil. The topsoil, to a depth of 10 inches, is rich-brown or slightly reddish brown friable calcareous fine sandy loam. Below this and extending to a depth of more than 6 feet is a rich-brown friable calcareous fine sandy loam layer that contains a few lenses of loam and clay loam. When the material of this layer dries, it becomes chocolate brown.

This soil occurs in many areas on both sides of Pecos River. Nearly all the areas north of United States Highway No. 380 are highly impregnated with salts, but most of those south of the highway are free from high accumulations. Following installation of a drainage system that will keep the water table from 6 to 8 feet below the surface of the ground, this soil can be reclaimed by a comparatively small amount of flooding and leaching. Saltgrass grows on the salt-affected areas, but most of the other areas are cultivated to cotton, alfalfa, corn, and truck crops, and good yields are reported.

Arno fine sandy loam, better drained phase.—The better drained phase of Arno fine sandy loam differs from typical Arno fine sandy loam mainly in color and in its superior drainage. The areas near Berrendo River are lighter in color, approaching light chocoloate brown or brown when dry but becoming slightly more red when moist. The areas adjacent to Felix River are nearly as red as areas of typical Arno fine sandy loam. The bodies near Berrendo River consist of materials that have been deposited by flood waters of this river. In many places the soil material is very deep, but in some places it is a little less than 6 feet to soil material that is characteristic of the Reeves soils.

This soil is free from harmful accumulations of salts throughout, and most of the land is cultivated. It is very easy to cultivate and irrigate, and it produces very good yields of alfalfa, cotton, grains, and apples, which are the main crops grown.

Arno clay loam.—Arno clay loam differs from Arno loam principally in its heavier texture. The 10-inch topsoil consists of friable calcareous clay loam which, when dry, is rich dark brown or chocolate brown but when moist has a more pronounced red color. Below this and extending to a depth of 6 feet or deeper, is rich dark-brown rather friable clay loam interstratified with a few lenses of clay and loam.

The two small areas of this soil lying about 4 miles northwest of Spring Mountain Valley School consist of materials that have been transported from the adjacent uplands to the east, and they are redder and contain more gypsum than the typical areas. The part

of the body that is free from salt accumulations, about 6 miles east of Roswell, has a slightly darker topsoil than typical and is potentially a more fertile soil.

This soil occurs in a number of bodies on both sides of Pecos River. The surface relief is smooth, and most of the land has a slight slope parallel to the general direction of the river flow. About one-third of the soil is affected in some degree by an accumulation of salts, and parts of some areas have been artificially drained and reclaimed. Reclamation of this land is possible, but in most places it requires flooding and leaching for a longer period than is required for coarser textured soils. The salt-affected areas produce mainly saltgrasses, but the salt-free areas are cultivated. More power is necessary to plow and pulverize this soil than is required for coarser textured soils. Alfalfa and cotton are the principal crops grown, and good yields are obtained.

Arno clay loam, better drained phase.—Arno clay loam, better drained phase, is very similar to typical Arno clay loam, but in some places it has a darker topsoil of higher organic-matter content. The large body at Roswell has a clay loam texture throughout and in places show slight indications of profile development. About three-fourths of a square mile of the eastern extremity of the area near Roswell contains a few thin strata of gray ashy gypsum, ranging from one-half inch to about 3 inches in thickness and occurring at different depths between 6 inches and 6 feet below the surface. The gypsum layers lower crop production slightly and are in some places a hindrance to irrigation because of the loss of water that follows the more porous layer rather than passing down to the lower soil layers. In some places the gypsum washes out, leaving an open passage where irrigation water escapes from the soil until the overlying soil settles and fills the opening.

This soil differs somewhat from typical Arno clay loam in origin of the soil materials which have been deposited by the smaller streams originating in the mountains west of the area. The soil occurs in several places near these streams. The surface relief is smooth and slopes very gently toward the stream channel and parallel with the course of the stream. Drainage is good in most bodies, although in a few places it is poorly developed and salts have accumulated. Reclamation of the salt-affected areas depends on the installation of a system of drainage that will keep the water table from 6 to 8 feet below the surface. Where free from accumulations of salts, the land is used for growing alfalfa, cotton, corn, and truck crops, and good yields are reported.

Arno clay.—Many characteristics of Arno clay are similar to those of other soils of the Arno series. The topsoil, which extends to a depth of 10 inches, is dark rich-brown or light chocolate-brown calcareous clay. Below this layer and extending to a depth of more than 6 feet, is chocolate-brown slightly compact calcareous clay.

This soil occurs on the present or old stream flood plains in places where the finer textured materials have been deposited. Several bodies are in the eastern and southeastern parts of the area on both sides of Pecos River. The surface relief is very smooth, and the areas are nearly flat or have a very slight slope. Owing to the fine texture of this soil, internal drainage is poorly developed. Salts have accumulated in many places, but in some places drainage and

leaching operations have rid the soil of harmful quantities of salts. Where affected with very large accumulations of salts, the land is bare of vegetation, but other salt-affected areas have a sparse or moderate stand of saltgrass. The areas free from salts are rather hard to cultivate but are used for growing alfalfa and cotton, and fair or good yields are obtained.

Arno very fine sandy loam.—Arno very fine sandy loam differs from other soils of the Arno series mainly in texture which is a little finer than that of Arno fine sandy loam. The 10-inch topsoil is rich-brown or pale reddish-brown friable calcareous very fine sandy loam. Underlying this and extending to a depth of more than 6 feet is rich dark-brown calcareous loam containing some strata of clay loam or clay.

Many bodies of this soil occur near Pecos River. In general they have smooth surface relief and a very gentle slope. Water passes through the soil freely, and in many places drainage is very good, but in some places seepage water or water from lakes stands at or near the surface. Where such conditions exist, salts have accumulated, and the soil produces mainly saltgrasses. Where this soil is well drained it is very easy to cultivate and irrigate and is used for growing cotton, alfalfa, and corn, very good yields of which are reported.

Arno loamy fine sand.—Arno loamy fine sand is derived from materials that have been deposited mainly by Pecos River in much the same way as other soils of the Arno series, but this soil, following deposition, has been somewhat reworked by winds, resulting in a slightly hummocky surface relief characterized by wind-blown ridges or dunelike knolls, rising from a few inches to about 8 inches higher than the general surface level. The soil occurs in several small scattered bodies rather close to Pecos River. In general, the land, though rolling or hummocky in some places, is nearly level or gently sloping. Drainage ranges from good to excessive, and salts occur in only small quantities in a few places where the soil is affected by a high water table. Very little of the land is cultivated, as it is too sandy to be appreciably fertile, too leachy for efficient yields with average quantities of irrigation water, and too loose to keep from blowing if cultivated. Some bunch grasses (*Andropogons*) and some trees (saltcedar and cottonwood) grow on this land.

DARK-COLORED SOILS

Pecos loam and Pecos clay, although of small extent, are potentially the most fertile soils of the Roswell area. Areas in the vicinity of Roswell, which are well drained and free from salts, are used largely for the production of truck crops. Acre yields of these crops cannot be definitely stated, but very good yields of cabbage, onions, celery, green beans, spinach, and carrots are obtained. Two crops of vegetables are grown on most of the land each year, and most of the truck crops are marketed locally. Alfalfa yields more than 3 tons an acre. Potatoes are not extensively produced and apparently are not well adapted to climatic conditions.

Pecos clay.—Pecos clay is related to soils of the Arno series, but it has a much darker topsoil or is darker throughout all the soil layers. The topsoil, extending to a depth of 12 inches, is dark dull-brown

or black calcareous clay that breaks into small angular clods. Below a depth of 12 inches and extending to a depth ranging from 2 to 5 feet, but averaging about 3 feet, is compact calcareous dark dull-brown or black clay. Beneath this layer and continuing through the rest of the soil mass to a depth of 6 feet or deeper, is lighter grayish brown compact calcareous clay which probably contains some gypsum crystals, carbonate of lime, and other associated salts. A narrow margin extending about 1 mile along the northwestern part of the body of this soil near Roswell contains a few thin lenses of gypsum. Where the gypsum layers are numerous, are more than 1 or 2 inches thick, and occur in the upper 3 feet of the soil, the land is not so highly productive. Under irrigation these layers or lenses in some places are removed from the soil by seepage or underground waters, forming depressions, or sinks.

Pecos clay, though developed by processes similar to those responsible for the development of the Arno soils and their better drained phases, has a darker colored topsoil, probably owing in part to the deposition by surface floods of sediments that were higher in organic matter than the material accumulated to form the Arno soils. In the greater part of this soil, however, the darker color has developed in place after deposition of the mineral sediments. The areas were poorly drained, and in some places marshy conditions prevailed, and, under these conditions, water-loving plants thrived and decomposed, accumulating a large quantity of organic matter, which imparted a dark color to the upper layers of the soil. Where this soil has been reclaimed by drainage, the salt-free areas are highly productive.

Nearly all of this soil is adjacent to Hondo River. It has smooth surface relief and occupies very slightly sloping areas. Surface drainage is poor, and natural internal drainage ranges from poor to fair. Because this soil occupies a low position compared with that of adjacent soils, it receives rather large quantities of seepage water from the higher lands. Natural drainage has been supplemented by artificial drains to such an extent that most of the large areas near Roswell are now well drained and free from harmful accumulations of salts, although a small part of the land remains poorly drained and is affected by salts.

Practically all of this soil that is free from salts is cultivated. Alfalfa occupies the larger part of the land, although much of the area near Roswell is farmed rather intensively. Truck crops occupy a large acreage, and the production of nursery plants and flowers is important. This soil forms large hard clods if not well farmed and is much harder to handle than most of the coarser textured soils of the area, but where properly handled it yields as much or more than the other soils.

Pecos loam.—Pecos loam is closely related to Pecos clay, but it has a lighter textured topsoil which extends to a depth of 10 inches. It consists of dark dull-brown mildly calcareous friable loam that has a small-clod structure. Below this and extending to a depth of about 3 feet, the soil is much darker and is clay loam or clay in texture. The material in both layers becomes darker when wet. Below a depth of 3 feet is lighter chocolate brown compact calcareous clay loam or clay. Thin lenses of ashy gypsum may occur at any depth.

Areas of this soil occur near Hondo River and North Spring River, associated with other soils of the Pecos and Arno series. The surface relief in most places is smooth and very slightly sloping. Drainage conditions are similar to those in areas of Pecos clay, that is, some areas are well drained and free from harmful accumulations of salts, whereas others contain salts to some degree. Reclamation of salt-affected areas by draining and leaching is possible in most of this soil, and it is as adaptable to reclamation as Pecos clay. Most of the salt-free areas are cultivated and produce very good yields of truck crops, alfalfa, and cotton.

STREAM-VALLEY SOILS WITH PARTLY DEVELOPED HORIZON OF LIME AND GYPSUM ACCUMULATION

The soils of this group are represented by the Navajo soils, which occupy a position somewhat higher than the Arno soils and appear to have been developed on stream-terrace remnants above the soils of the flood plains. They represent an older but comparatively youthful stage in soil-profile development. Both surface soil and subsoil materials are highly calcareous, but there is a decided accumulation of lime in the subsoil, with more or less mottling and segregation of the lime in the form of light-colored blotches and seams. This feature is, however, much less pronounced than in the older and much more mature soils of the Reeves series.

These soils are somewhat better drained than the Arno soils, are subject to infrequent overflows, and are, with the exception of a few local areas, free from excessive accumulations of salts. They are used mainly for alfalfa, corn, cotton, and grain crops, and good yields are generally obtained.

Navajo loam.—The topsoil of Navajo loam, extending to a depth of about 18 inches, is light reddish-brown or dull-red highly calcareous friable loam, in which the red color is pronounced when wet. Below this layer is slightly compact heavy loam that is friable when moist but is slightly cemented when dry. It is light reddish brown or pale red, with a large number of gray flecks and spots where carbonate of lime and crystals of gypsum have accumulated. Below a depth of 34 inches and extending to a depth of more than 6 feet is loose but friable pink or pale reddish-brown highly calcareous loamy fine sand. The loose sandy material forms the subsoil of most of the soil, but in some places a heavier loam or clay loam forms the subsoil or occurs in thin lenses interstratified with the loose sandier material.

This soil is associated with Navajo clay loam east of East Grand Plains School, and a few bodies lie east of Pecos River. The surface relief is smooth and gently sloping. With the exception of the body about 4 miles east of Orchard Park, a part of which contains moderate quantities of salts, nearly all the land is cultivated. The principal crops are cotton, alfalfa, corn, and grains, and very good yields are obtained.

Navajo fine sandy loam.—The characteristics of Navajo fine sandy loam are very similar to those of Navajo clay loam, but the texture is somewhat lighter. The topsoil, to a depth of 20 inches, is rich reddish-brown or dull reddish-brown calcareous mellow fine sandy

loam. Below a depth of 20 inches and extending to an average depth of 36 inches is slightly compact light reddish-brown or pale-red loam or fine sandy loam, which has some gray mottlings where carbonate of lime has accumulated. Below a depth of 36 inches and extending to a depth of more than 6 feet is loose highly calcareous pinkish-gray or pale-red fine sand or fine sandy loam.

An area that is somewhat different from the typical soil occurs about 4 miles east of Orchard Park, where a part of the soil material has been blown in from nearby areas of Arno loamy fine sand and a part of it has been washed in from the Permian "Red Beds" formations that occur in the substrata of the body of Reeves chalk bordering this area on the east. Some gypsum crystals occur throughout all layers of this body of soil.

The areas about one-half mile east and south of Spring Mountain Valley School are characterized by a large number of low hummocks or knolls that extend from a few inches to about a foot above the general level of the surface. These consist of loamy fine sand that has been blown in from the nearby area of dune sand.

The origin and mode of formation of most of this soil is similar to that of Navajo loam and Navajo clay loam. It occupies mainly smooth-surfaced gently sloping areas. Drainage is very good, and in some places, owing to the loose sandy subsoil, the soil is leachy. It is all free from harmful accumulations of salts, and most of it is used for growing crops, mainly alfalfa, corn, cotton, and apples, and good yields are reported.

Navajo clay loam.—The 15-inch topsoil of Navajo clay loam is light chocolate-brown friable highly calcareous clay loam. Below this and continuing to a depth of about 32 inches is light grayish-brown friable clay loam. The gray cast of the material in this horizon is caused by the large number of gray carbonate of lime accumulations and a smaller number of gray gypsum accumulations. Below a depth of 32 inches the material is light grayish-brown or dull-yellow clay loam or clay, high in carbonate of lime and containing a few gypsum crystals. This horizon extends to a depth of 6 feet or deeper.

This soil occurs in only one area, about 3 miles east of East Grand Plains School, where it occupies, presumably, a remnant of an old river terrace which merges almost imperceptibly with the upland plain occupied by the Reeves soils. The soil-forming material is redder than in the soils of the Reeves series. It is probable that this soil occupies an old river flood plain of Pecos River, and the geological origin of the materials has been in the vicinity of the headwaters of the river, where there are many red sandstone and shale formations. The surface relief is smooth, and the slope of the land is very gentle. Drainage is good in most places, but seepage water approaches the surface in a low spot just east of the Northern Canal. High accumulations of salts occur in part of this seeped spot, and moderate or small quantities are present in other parts of it. Saltgrass occupies the areas having a high accumulation of salts, and barley and cotton are grown on the areas where salt accumulations are sufficient to affect crops but slightly. Very good yields are obtained on the well-drained parts of this soil.

STREAM-VALLEY SOILS WITH EXCESSIVELY DEVELOPED HORIZON OF LIME AND GYPSUM ACCUMULATION

This group is represented by Pecos loam, gray-subsoil phase.

Pecos loam, gray-subsoil phase.—The gray-subsoil phase of Pecos loam is similar to the other Pecos soils in occurrence and in its relation to the associated soils. The 12-inch topsoil is very dark grayish-brown friable calcareous loam, but two small areas mapped about 1 mile southeast of Lake Van have a clay loam topsoil. Below a depth of 12 inches and extending to a depth of 6 feet or deeper, the material is gray highly calcareous clay loam. The subsoil material differs somewhat in different bodies and at different places within a body.

Nearly all of this land is poorly drained, and the water table stands at different levels in different areas. The grayness of the subsoil is in part due to an accumulation of lime and gypsum, that has been precipitated as the result of a high water table. Variation in the height of the water table and concentration of gypsum and carbonate of lime in the seepage waters have given rise to gray layers near the surface in some places and at a depth of 3 feet or deeper in other places. The quantity of gypsum or carbonate of lime accumulated differs in different places. The body bordering South Spring River in sec. 9 and a part of the area in sec. 8, T. 11 S., R. 25 E., contains so much gypsum and other salts that it is practically worthless except for a small amount of poor-quality pasture grasses. The gypsum is in a soft mealy form in places, and in other places it is associated with various quantities of carbonate of lime and is in the form of hard rocklike masses, many of which protrude from a few inches to about 2 feet above the surface of the ground. Nearly all of this soil is moderately or highly impregnated with salts, as most of the areas occur in troughlike locations or in places where excessive amounts of seepage waters accumulate. Drainage and reclamation of some of the land is possible, but it is not recommended at this time because of the large cost of an adequate system of drainage necessary to care for these areas and the comparatively poor quality of much of the soil even following reclamation. The small part of the body bordering South Spring River, which has only a slight salt accumulation, is cultivated to cotton, barley, and corn, but only poor or fair yields have been obtained.

MISCELLANEOUS LAND TYPES

In addition to the soils which have been classified, with respect to their relation to each other, into soil series and soil types, a number of associated land types of variable character, which do not lend themselves to such classification, have been identified and mapped. These include peat, dune sand, rough broken land, and river wash.

Peat.—Peat in this area consists principally of raw undecomposed fragments of roots and stalks of sedges, tules, and cattails, that are growing in marshy areas. When dry, the color of the organic material ranges from grayish brown to dark brown.

Peat occurs in three bodies—two of which are west of Pecos River in the northeastern part of the area and the other about 4½ miles east of East Grand Plains School. The two northern areas are very

marshy, and the water table stands on or near the surface much of the year. In places the peat material is developed on gypsum formations which occur 3 feet or more below the surface, but in places where peat borders the gypsum a number of islands of gypsum extend up to or near the surface of the peat, and there is a rather large quantity of finely divided particles of gypsum among the sedge and tule roots. In parts of these peat areas, water is flowing slowly to the south and southeast. Much of the water from Bitter Lake flows into an area of peat, the channel of Bitter Creek branching as it enters the peat area and being lost within a short distance. The water flows slowly and is brackish, and most of the area contains water high in salts. Reclamation of this area would include the expense of a drainage system that would control the water table, and the value of such a procedure is questionable because of the possible upward movement of water from below. If it were possible to drain this land successfully, any program undertaken should include control of the water table, and even with the water table controlled the lack of mineral material in this raw fibrous organic material would preclude an exceptional value of this land for crop production. If this material were allowed to dry, loss by desiccation of the material or by fire might occur. The organic material in the area east of East Grand Plains School ranges from 2 to 4 feet in depth, and below this the soil material is very similar to the subsoil of Arno fine sandy loam.

Dune sand.—Nearly all the dune sand areas lie on the eastern side of Pecos River. Most of them are close to the river and have been built up mainly from sandy alluvial sediments that have blown from the channel of the river. They consist of mildly calcareous brownish-gray or faint reddish-brown sands and fine sands blown into dunes that rise from about 2 to more than 10 feet above the general level of the land surface. Though the sand of most of the dunes has been blown from the bed of Pecos River, it is probable that much of the dune sand material near the margin of the area surveyed, east and southeast of Hagerman, has been derived from nearby areas of rough broken land where sandy strata of the Permian deposits are exposed and eroded, as the dune sand in that vicinity is more red than in areas nearer Pecos River. All the dune sand consists of material high in quartz, and it is loose in consistence to a depth of more than 6 feet. Drainage is excessive, and there are no appreciable accumulations of salts.

Dune sand supports a scant stand of tall bunch grass, and many of the areas bordering the river channel support a growth of saltcedar and a few mesquite trees. A sparse or moderate stand of mesquite brush and trees, ranging from 2 to 6 feet in height, are the predominant vegetal growth on the dunes near the margin of the area southeast and east of Hagerman. The small amount of pasture provided by the grasses, the mesquite brush and trees, and some weeds that thrive following spring and summer rains constitute the only agricultural value of the dune sand areas.

Rough broken land.—Rough broken land occurs mainly near the eastern margin of the surveyed area where eroded exposures of geological formations of Permian age occur. These eroded lands are classified by the United States Geological Survey as belonging to the Chupadero formation which consists of limestone, gypsum, and gray and red sandstones. Strata in these formations range from soft ma-

terial that may be easily eroded to rocklike material that withstands much erosion by either wind or water. Most of the areas of the Chupadero formation east of Pecos River are highly eroded and rise to a height ranging from about 6 feet to as much as 150 feet above the level of the surrounding land surface. All the material here is highly calcareous, and many strata contain a large quantity of soluble mineral salts. These areas support a scant growth of short grasses that are not nutritious.

The areas west of Pecos River include steep and eroded slopes where upland alluvial fans break to join with lower lying areas or where a stream has cut a channel deep into the upland sediments. The soil materials of these areas are very much like the adjacent upland soils, or in many places they are similar to soils of the Pinal series. Most of these areas support a moderate stand of nutritious short grasses and brush, that provides some feed for livestock, but otherwise they have no agricultural value.

River wash.—River wash includes sediments ranging from clay to coarse sand and gravel but predominantly are fine sand, or sand which occupy stream-bottom areas adjacent to the river. Many of these areas are cut by channels formed by waters that have flowed through the area during comparatively recent floods. The material is mainly sand high in quartz and has a loose consistence. Most of this sandy material has been leached of salts, but in places where water has stood near the surface for long periods, high accumulations of salts occur on the surface. Most of the areas of river wash are barren or support a moderate or dense stand of saltcedar ranging in height from 3 feet to as much as 15 feet. This land has no agricultural value.

A few areas bordering Felix River, to a depth of more than 6 feet, contain large quantities of water-worn and rounded gravel, principally of sandstone origin, with little fine interstitial soil material. The gravel has been transported from formations west of the area and deposited by flood waters of Felix River. These areas have smooth surface relief, and in most places the slope is gentle. The loose gravel render this soil too leachy to be of value under cultivation. A sparse stand of short grasses, providing a small amount of pasturage, and catclaw, a low-growing bush, constitute the vegetation.

SOILS AND THEIR INTERPRETATION

Climatic environment and especially vegetation are the primary factors in the development of soil characteristics. Locally these influences react on the different soil materials and tend to produce somewhat similar characteristics in each soil, but in this area a number of local influences have inhibited or altered soil development, with the result that differences in the soil profiles have occurred—some have resulted from the chemical characteristics and the texture of the parent material, and others are the result of surface relief, drainage, erosion, or degree of development.

Most of the soils west of Pecos River have developed from materials that have been transported from the Sacramento Mountains. The larger part of the area contributing these materials consists of limestone, gypsum, and gray and red sandstones of the Chupadero

formation which is a formation of Permian age.[4] It is probable that part of the material has been eroded and transported from areas where older sedimentary deposits and some igneous porphyries are exposed.

Soils of the Reeves series represent the most extensive and important soils of the area and are characteristic of a normally developed soil for this section. Reeves loam has been developed on smooth-surfaced gently sloping alluvial fans, from sediments that have been deposited by stream and surface flood waters having their origin in the Sacramento Mountains west of the area surveyed. Most of the materials accumulated have been eroded from various strata of limestone, gypsum, and gray and red sandstones of the Chupadero formation, although some have been transported by Hondo River or by streams whose sources are in the vicinity of Hondo River, and probably they have originated in igneous porphyries and in sedimentary rocks that are geologically more recent than the Chupadero formation. Following accumulation, these sediments have been subjected to soil-developing processes peculiar to the southwestern desert or semidesert conditions, and the present characteristics of the soil have been developed. The influence of vegetation is less marked than in the somewhat more moist areas of the semiarid regions where the tall grasses have produced the Chernozem, or black soil. The principal soil-developing influences have been oxidation of some of the minerals of the soil and translocation of salts from the upper layers to the subsoil. Probably some of the more soluble salts have been entirely removed.

The exceptionally large amounts of bases in the soil material of this area, though some leaching has occurred, are still high in all the soils. This is indicated by the pH determinations, as given in table 3. No other analyses have been made to determine other chemical or physical changes due to soil development.

TABLE 3.—*pH determinations of 4 soils from the Roswell area, New Mexico*[1]

Soil type and sample no.	Depth	pH	Soil type and sample no.	Depth	pH
	Inches			*Inches*	
Reeves loam:			Reagan clay loam:		
500820	0- 8	8.3	500816	0- 8	8.3
500821	8- 20	8.2	500817	8-20	7.9
500822	20- 32	8.2	500818	20-34	8.2
500823	32- 72	8.2	500819	34-96	8.0
500824	72- 96	8.1	Navajo loam:		
500825	96-112	7.8	500832	0-18	8.0
Reeves chalk:			500833	18-34	8.3
500801	0- 18	8.2	500834	34-72	8.0
500802	18- 72	8.0			

[1] Determinations made with the hydrogen-electrode, by E. H. Bailey, Bureau of Chemistry and Soils.

The surface soil of Reeves loam is composed of rather fine soil materials that form a very thin fragile surface crust in places where no vegetation grows. This soft cementation is probably owing to a small quantity of soluble minerals that are deposited following evaporation of moisture from the surface. Where covered with grass, weeds, or brush, no crust is formed and the material is friable. The

[4] DARTON, N. H. GEOLOGIC MAP OF THE STATE OF NEW MEXICO. U. S. Geol. Survey 1928.

8-inch topsoil consists of light-brown or pale reddish-brown highly calcareous friable loam of small-clod or single-grain structure. In most places it contains many plant roots but almost no other organic matter or humic residues. Below this the soil material does not contain so many plant roots, and it is somewhat firm or slightly cemented but very mellow. The cementing materials presumably are carbonate of lime and associated salts. At an average depth of about 20 inches and extending to a depth of about 30 inches the material contains many small gray flecks of carbonate of lime. A large number of plant roots and a large number of worm casts occur in the topmost 30 inches of soil. Below a depth of 30 inches the base color of the soil is olive brown or pale reddish brown, and the material is highly mottled with gray carbonate of lime accumulations. The soil material is weakly cemented but friable heavy loam or light clay loam. The heavier texture is not everywhere present at this depth and, presumably, this is not an illuviated layer but occurs as a stratum of comparatively fine-textured material. This horizon extends to an average depth of about 6 feet, below which and extending to a depth of about 8 feet is slightly compact weakly cemented clay of olive-brown or light reddish-brown base color, highly mottled with gray carbonate of lime. A few of the carbonate of lime nodules are irregularly rounded and range from the size of a pinhead to one-eighth inch in diameter. There are a few rust-brown stains of iron oxide in this horizon. Below a depth of 8 feet the material is highly calcareous but does not contain so many nodules or so much carbonate of lime as the horizon above. A few crystals of gypsum are apparent in this material.

This soil has been developed from highly calcareous water-laid deposits. The principal change effected has been partial leaching of soluble materials from the upper layers of the soil and their accumulation in the lower layers. Gypsum and the more readily soluble salts have been partly or completely leached below the solum, and some of the carbonate of lime has been carried down from the upper soil layers and deposited in the lower layers. This soil does not have all the characteristics commonly present in mature soils of the southwestern desert regions, and it seems not to have reached the degree of maturity evident in the Mohave soils of these regions. The surface soil is not leached of lime but is moderately calcareous, and the subsoil contains no zone of illuviated clay accumulation. The clay contained in the soils of this area has not been deflocculated as it has in many other areas, probably owing to the high content of gypsum in the soil materials. The gypsum reacts with any sodium in the soil material to form sodium sulphate, thus preventing saturation of the soil with an excess of the sodium ion. The excess of calcium and the prevention of the accumulation of an excess of the sodium ion promotes flocculation and prevents deflocculation of the clay particles. Gypsum crystals are more common in this soil than in soils of the Mohave series, probably owing to the higher content of gypsum in the parent material.

The reddish-brown color of Reeves loam denotes the presence of iron oxides, and the fact that the red color predominates indicates that very little dark staining of the soil by decomposed grass or plant debris has occurred. Although this is the normal soil for

this area, it is pedologically immature. The materials from which it is developed are of secondary origin, and most of them are well weathered, as mica and readily decomposable minerals are weathered beyond recognition. The gritty mineral part of the soil consists of clear or milky subangular quartz and subangular dark-brown fragments that apparently are high in iron.

This soil occurs on smooth-surfaced gentle slopes. It absorbs moisture readily, and surface floods occur only following exceptionally heavy rainfall from thundershowers. The soil is friable and readily penetrated by plant roots, easily cultivated, fairly retentive of moisture, and, where well drained, is productive. It is used for nearly all the crops grown in the area.

This soil is very closely related to many other soils of the area. Those in the same series, but differing principally in texture of the topsoil or of both the surface soil and subsoil, are Reeves clay loam, Reeves fine sandy loam, and Reeves clay, together with included variations and phases.

Reeves chalk is a gray or white ashy material especially high in calcium sulphate and carbonate of lime. It occurs generally as a part of the Chupadero formation. It is possible that some of the bodies in this area are the product of precipitation from seepage waters in poorly drained areas. This material is in general high in soluble salts.

Reagan clay loam differs from the Reeves soils only in having a darker topsoil. The darker soil extends to an average depth of about 8 inches but ranges from about 4 inches to as much as 18 inches in thickness. The darker color of the surface soil material has resulted from incorporation of humic residues which, in some places, have developed from plants that grew in poorly drained moist places; and in other places, including the area south and southeast of Roswell, the dark-colored soil material has been deposited by flood waters that have entered the area from Hondo River. During exceptionally heavy rains in the uplands west of the area, surface floods have carried considerable soil material, vegetal debris, and decomposed organic matter into the channel of the river, resulting in flood waters from this river spreading over large areas south and southeast of Roswell and depositing these materials.

Soils of the Pinal series occur either on the same alluvial fan and approximately on the same plane or level with the Reeves soils or in areas that are elevated from 1 to as much as 10 feet above the general level of the plain on which the Reeves soils occur. These soils owe their character to either an older or more maturely developed stage of the soil material, or to an abnormal soil development resulting from an earlier condition of poor drainage or evaporation of mineral-laden waters from the soil.

Pinal gravelly loam and Pinal loam occupy higher elevations than adjoining areas of the Reeves soils. The topsoil of Pinal gravelly loam, extending to a depth of about 10 inches, is light-brown or light grayish-brown friable gravelly loam that contains many angular fragments of carbonate of lime and numerous grass roots in most places. The gravel are well water-worn or subangular and are mainly of sandstone material, but a few are of igneous origin. In

most places this soil is covered with grasses, weeds, or brush, and the topsoil contains many fine plant roots. A few dark-colored soil particles occur, some of which probably are derived from worm casts and others from root holes that have been filled with dark material from decomposed roots. Below a depth of 10 inches and extending to an average depth of 24 inches is light-gray or white firmly cemented gravelly loam which is very high in carbonate of lime, the principal cementing material. Below this indurated horizon and in most places extending to a depth of 6 feet or deeper is friable gray or white highly calcareous gravelly loam. This soil has a friable topsoil corresponding to the topsoil of the Reeves soils, a zone of high carbonate of lime accumulation, and the parent material containing a smaller quantity of carbonates. In this climate the rainfall has been comparatively low, but it has been sufficient to dissolve the more readily soluble salts in these soils, carry them from the topsoil, and deposit them in the subsoil. Appreciable amounts of gypsum and large quantities of carbonate of lime have been deposited and have formed an indurated hardpan. The rather high percentage of calcium carbonate in the surface soil may be owing to deposition by evaporation, or the original topsoil may have been eroded, leaving the upper part of the zone of accumulation as the present surface soil.

Pinal clay loam occurs on alluvial fans either on the same plane as the Reeves soils or on the breaks or slopes where the alluvial-fan areas merge with lower lying soils. Where areas occur on the same plane with the Reeves soils, the calcium carbonate and other salts forming the indurated hardpan have been accumulated in poorly drained areas where the movement of highly impregnated saline water has been restricted, and the salts have been precipitated at the level of the ground water through evaporation of the solution. Another theory is that the hardpan layer was formed in a manner similar to that described in the development of Pinal gravelly loam and that erosion removed the more friable soil above the hardpan and, subsequently, other materials that correspond to the topsoils of the Reeves soils were deposited from surface flood waters. In the areas on the steeper slopes or breaks of the alluvial fans, it is probable that the hardpan has been developed by deposition of carbonate of lime and other salts from evaporation of mineral-laden seepage waters.

The Navajo and Pecos soils represent materials which have been deposited as alluvial sediments from waters of the present-day streams which traverse the area. They have not occupied their present position long enough to have developed profile characteristics of a fully developed soil and they represent an unmodified or incipient stage in soil development. They consist of light reddish-brown, very dark dull-brown, or nearly black mildly or moderately calcareous materials—the Arno comprising the lighter colored and the Pecos the darker colored soils. Some of these soils have a uniform structure and texture to a depth of 6 feet or deeper, whereas others consist of irregularly variable strata of materials that differ in compactness, structure, and texture. Soils that occur on the old flood plain of Pecos River and soils of the flood plains of the smaller streams tributary to this river show slight differences in color.

These probably, are owing to differences in the parent material, drainage, and organic-matter content. Where the soils are well drained and free from harmful accumulations of salts they are very fertile and well adapted for growing nearly every variety of crop produced in the area. The Navajo series includes areas of soils which occupy terracelike positions and represent an older and more nearly mature stage of soil development. Bodies having somewhat better developed drainage than typical are also included.

Peat occupies marshy tracts between areas of Reeves chalk and the soils of recent alluvial deposition on the river flood plains. Reeves chalk of the upland terrace, which joins the area of peat at its western margin, is from 10 to 40 feet higher than the level of the peat, whereas the soils that join the peat area on the east are either very slightly above or only about 2 feet higher than the surface of the peat. Seepage water from the areas of Reeves chalk and from underground sources northwest of the largest area of peat contribute to the flow of water that moves slowly through this land. A sample of peat from this area is described by A. P. Dachnowski-Stokes, of the Bureau of Chemistry and Soils, as follows:

0 to 18 inches, grayish-brown coarse fibrous slightly silty sedge peat, derived mainly from roots and underground stems of marsh plants such as tule (*Scirpus*), sawgrass (*Cladium*), rushes, and cattails, The material is porous, coherent, and contains small shells and comminuted parts of univalve mollusks, together with a small quantity of sediment from overflow.

18 to 60 inches, brown or gray-brown stringy fibered tule (*Scirpus*) peat which is poorly decomposed, porous, and contains an admixture of roots and rhizomes from a variety of sedges, small quantities of silt, and a few shells of mollusks.

WATER SUPPLY AND IRRIGATION

Livestock raising was important and had been encouraged in the Pecos Valley for many years previous to 1889, but irrigation had been discouraged and was confined to a few small farms. In 1889, and soon thereafter, ditches were constructed to divert water from North Spring River, South Spring River, and Hondo River, the latter receiving drainage from Berrendo River. The water in these streams was derived from local springs, and the flow was limited. A source of artesian water was discovered in 1891 when a well was drilled to supply water for the city of Roswell. The earlier wells were used chiefly for water for livestock and domestic purposes, and it was not until about 1903 that drilling artesian wells for irrigation assumed proportions of consequence. In 1900, 153 artesian wells were in the valley; by 1906, 485; and by 1910, about 1,080. The flow of the springs along South Spring River and at many other places decreased or stopped when a large number of wells had been drilled, and irrigation from wells expanded. In 1925, 60,000 acres were irrigated in the valley with water derived either directly or indirectly from artesian sources. The original area of the artesian basin comprised 663 square miles, but, owing largely to the heavy draft on the artesian reservoir, it decreased to 499 square miles in 1916 and to 425 square miles in 1925. The quantity of water annually derived from wells is about 200,000 acre-feet, and the total discharge at the surface from all sources is about 250,000 acre-feet. Recharge

to the artesian reservoir is derived from rain and snow that falls on a catchment area of about 4,000 square miles situated west of the artesian basin and extending to the crest of the Sacramento Mountains. Rights to artesian water within the basin are acquired by appropriation under the provisions of a law passed by the tenth session of the New Mexico Legislature.

The wells that penetrate the artesian reservoir range from 175 to 1,587 feet in depth, but most of them are between 250 and 800 feet. Some of the wells have a high pressure and throw water many feet above the surface, others flow, and in still others the water does not rise to the surface, but pumps are used to lift the water for irrigation. The flow differs in different wells, depending on such factors as the depth of the water-yielding strata penetrated, the permeability of the aquifers, and the type of well. In some parts of the area the water-yielding strata are dense and yield water so slowly that the flow is too small to care for irrigation needs. In other places, however, there is an exceptionally large flow. A well drilled on the Oasis ranch, which is located a few miles east of East Grand Plains School, flows 9,225 gallons a minute, or 20.5 second-feet. This, so far as is known locally, is the largest flowing artesian well in the world.

Besides the artesian wells, many shallow wells, ranging in depth from 10 to about 100 feet, derive water from the alluvial sediments of the valley filling. Many of these wells are for domestic use, but some have large pumps and are used for irrigation. The water ranges in quality from good to bad, depending on its content of dissolved salts. The area of shallow ground water is a comparatively narrow belt that parallels Pecos River, although a few areas of shallow ground water occur, in which impermeable layers hold the water from penetrating to the deeper water table. One such area is near Felix River a few miles west of Hagerman. Another source of irrigation water is Hondo River and its tributaries west of the area. Most of the water of this river, like that of many other streams coming from the Sacramento Mountains, is diverted for irrigation in the higher sections, or it sinks into the porous sediments several miles west of the area and enters the artesian reservoir, and it is only during exceptional floods that water flows in the eastern part of the channel. About 5 miles southwest of Roswell, several areas are irrigated from canals constructed to divert flood water from Hondo River, and water from Hondo and Berrendo Rivers and their tributaries is diverted to the Northern Canal for irrigation purposes.

A shallow furrow method of irrigation is generally used for cotton, all row crops, and orchards, and flooding with control borders is employed for alfalfa, other hay crops, and grains. For cotton and other row crops about 2 acre-feet of water is applied, for alfalfa about 3 acre-feet, and for orchards about 3½ acre-feet.

ALKALI AND DRAINAGE

Most of the important soil-forming rocks of this area contain soluble minerals which, on weathering and decomposition of the rocks, have been dissolved by water and carried in solution. Besides the soluble minerals from weathering rocks, mineral salts have

been carried in by underground waters that have dissolved the salts from the rocks and soils outside the area surveyed. In regions of low rainfall, such as this, the rate of evaporation is high, and nearly all moisture in the soils contains some soluble salts. In areas of arrested drainage, which have been subjected to seepage waters or a high water table that has stood at a depth of 3 or 4 feet below the surface for protracted periods, the salts have accumulated on or near the surface by evaporation of the soil waters containing the salts in solution.

In addition to the carbonate of lime and gypsum which are so abundant in the soils of this area and which are harmless or beneficial, except in unusually excessive quantities, there are other salts which become injurious to crops in comparatively small concentrations and are known as "alkali" salts, or soil "alkali." With the exception of the so-called "black alkali", they are for the most part not true alkalies but are neutral in chemical reaction.

In 1899, according to alkali and ground-water maps included with the soil survey in the Pecos Valley,[5] both "alkali" and water-table conditions were much more serious than at present. The kinds of "alkali" salts in the valley were studied at that time, and the principal salts identified were members of the "white-alkali" group rather than of the "black-alkali" group. Sodium sulphate, magnesium sulphate, calcium chloride, and sodium chloride are the principal salts found in this area. Nearly all the soil-forming material contains some gypsum, and in the presence of this, the more harmful "black alkali" (sodium carbonate) does not form or is converted into less injurious minerals. Where only the "white alkali" salts are present and the sulphates predominate, crops will grow under slightly higher percentages of total salts than in areas in which accumulations of sodium carbonate, sodium bicarbonate, or sodium chloride occur.

Most of the crops grown in this area do very well if the salt accumulation is not above 0.2 percent of soluble salts (calculated on the dry weight of the soil) in the topmost foot of soil or is distributed throughout the entire soil mass. Some crops thrive where as much as 0.3 percent of salts is present, but higher concentrations, either in the surface soil or distributed throughout the soil mass, affects crops proportionately to the salt content, soil texture, and other modifying factors. If the concentration is near or more than 1 percent, the growing of commercial crops is generally prohibited.

In the classification and mapping of land having an accumulation of salts in this area, four grades have been differentiated: (1) "Alkali-free" areas, in which "alkali" concentrations are less than 0.2 percent, so distributed through the soil as to have no appreciable deleterious effect on crops, indicated on the soil map by the letter **F**; (2) slightly affected areas, most of which contain between 0.2 and 0.4 percent of salts, so distributed as to only slightly affect crops and crop yields, indicated by the letter **S**; (3) moderately affected areas, most of which contain from 0.4 to 0.8 percent of salts, so distributed that the crop is weakened or in many places killed, indicated by the letter **M**, and including small spots where more than 1 percent of salts is present; and (4) strongly affected areas, most of

[5] MEANS, T. H., and GARDNER, F. D.

which contain more than 1 percent of salts concentrated in the topmost foot of soil or distributed throughout the soil mass, indicated by the letter **A**. Where the soils are strongly affected, crop production is prohibited until reclamation has been accomplished and the salts leached from the soil.

The highest accumulations of salts in this area occur in comparatively low sections, where subsurface or irrigation waters seep from higher lands, in the soils of the flood plains that parallel the rivers and streams, and in most of the bodies of Reeves chalk. Moderately and slightly affected areas occur in the vicinity of the strongly affected areas but at slightly higher elevations or in locations where the water table is somewhat lower and drainage is better developed.

Reclamation of salt-affected areas necessitates the installation of an adequate drainage system that will keep the water table from 6 to 8 feet below the surface and a system of leaching the salts from the soil by flooding the land with water, holding the water on the land until it penetrates downward, dissolves the salts, and carries them from the soil as the water passes out with the drainage. A comparison of the "alkali" map made in 1899 with the present map of this area indicates that many formerly affected areas have been reclaimed and are now productive.

Most of the reclamation has been effected through the organization of drainage districts and the drainage works constructed by them. Four districts occur in this area. Construction work on the Roswell drainage district was stopped in 1921. It represents an expenditure of $241,809.80. Near and east of Roswell, 43.8 miles of covered drains were installed. The East Grand Plains district, which is south of the Roswell district, was completed in 1917 at a cost of $93,209.97. This district includes 7,638 acres with approximately 26 miles of covered drains. The Dexter-Greenfield district, which includes 17,485 acres, was completed in 1921 at a cost of $425,720.80. The Hagerman district, which was constructed in 1919 at a cost of $143,455.69, includes 6,762 acres and has about 50 miles of covered drains. Many areas of salt-affected soils in each of these drainage districts have been reclaimed and are now productive, but some trouble has been experienced where soils that do not lend themselves well to reclamation have been included in the drainage district, or where tile drains have sunk out of line, owing usually to strata of gypsum that have washed out of the soil, and allowed the upper part of the soil or the tile to settle. The use of open drains in some soils would prove more effective. The East Grand Plains district has repaid all costs, but the other districts range from moderately to highly in debt.

It is probable that many of the slightly affected areas, where strata of gypsum do not occur, will eventually be reclaimed. It is not practical to reclaim any areas of Reeves chalk or many of the small bodies that occur in troughlike positions and receive excessively large quantities of seepage water. It is possible, though probably not economically feasible, to reclaim several areas of soils of the Arno series, as nearly all these soils lend themselves to reclamation, though longer periods of leaching and more expense are necessary on Arno clay or on areas where clay layers in the soil impede the downward penetration of water. The feasibility of reclama-

tion of these soils and of the gypsum-substratum phases of the Reeves soils is influenced by many factors, but the possibility in each area depends on adequate and effective drainage, leaching by flooding, and washing the salts down and out of the soil.

SUMMARY

The Roswell area is located in the Pecos River Valley and includes 295 square miles near and south of Roswell, the county seat of Chaves County. It covers the northern half of the area in which artesian water is available in this valley. It includes principally the recently accumulated soils that have been deposited on river flood plains of the stream bottoms and which have not undergone much profile development, and upland soils that have been developed on alluvial fans formed by meandering streams and surface flood waters, which show characteristics of soil-building processes under warm arid or semiarid conditions.

The climate is semiarid or arid, and the temperatures are moderate during both winter and summer. Precipitation is low, and irrigation is necessary.

Drainage, which is either natural or artificial, is good in most of the area, although some large bodies of soils are poorly drained and are affected by alkali.

Livestock raising is the most important agricultural enterprise. Among the cultivated crops, cotton occupies the largest acreage and is the principal cash crop. Alfalfa for hay is the second crop in importance, and this also is an important cash crop. The growing of corn, sorghums, apples, and various truck crops, and dairying and poultry raising are important.

The soil-forming materials have been derived mainly from limestones, gray and red sandstones, and deposits of gypsum.

The most extensive and important soils, considered as to utilization and pedological development, occupy the upland, or plains, part of the area and are classified in the Reeves and Reagan series. They include Reeves loam, Reeves clay loam, Reeves fine sandy loam, Reagan clay loam, and Reagan clay, with different phases, variations, and inclusions, and represent the more maturely and normally developed soils of the area.

Slightly developed soils, developed from materials of recent-alluvial accumulation, occupy the stream bottoms and are classified as soils of the Arno and the Pecos series. Some of these are poorly drained and affected by accumulations of salts but where free from salts are the most productive soils of the area. The Navajo soils are developed from alluvial deposits, like the Arno soils, but they show a moderate degree of soil development.

Soils of little or negligible agricultural importance include the Pinal soils, characterized by a firmly cemented hardpan substratum, Reeves chalk, river wash, dune sand, and rough broken land.

Areas having an accumulation of salts are classified in four grades which are delineated and indicated on the soil map by appropriate symbols.

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SOIL MAP
ROSWELL AREA
NEW MEXICO

NEW MEXICO AGRICULTURAL EXPERIMENT STATION
FABIAN GARCIA, DIRECTOR

Macy H. Lapham, Inspector, District 5.
Soils surveyed by W. G. Harper.

Lith. A. Hoen & Co., Inc.

Scale 1 inch - 1 mile
1 ½ 0 1 2 3 4 Miles

Field Operations
Bureau of Chemistry and Soils
1933